

S-6/PHSH/CC-14/23

TDP (Honours) 6th Semester Exam., 2023

PHYSICS

(Honours)

FOURTEENTH PAPER : CC – 14

Full Marks : 60

Time : 3 Hours

*Answer from **both** the Groups as directed.*

The figures in the margin indicate full marks.

*Candidates are required to give their answers
in their own words as far as practicable.*

GROUP—A

1. Answer any **six of the following questions :**

2×6=12

- (a) Explain the analogy of black-body radiation with ideal gas.
- (b) Mention the difference between Wien's distribution law and Rayleigh-Jeans law in relation with black body radiation.
- (c) What is thermodynamic probability?
- (d) What is Gibbs paradox?
- (e) What is 'Fermi energy'? Does it depend on temperature?

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[Turn Over]

(2)

- (f) What do you mean by strongly degenerate Bose gas?
- (g) At same temperature, which will exert greatest and least pressure — a gas obeying MB statistics or a gas of bosons or a gas of fermions?
- (h) Show that at high temperatures the FD distribution reduces to MB distribution.

GROUP—B

There are four questions from Question No. 2 to Question No. 5. Answer either (a) or (b) from each question given below : $12 \times 4 = 48$

2. (a) (i) State the Planck's law of black body radiation. Deduce Rayleigh-Jeans law from Planck's law of black-body radiation.
- (ii) What is radiation pressure? Show that the pressure due to diffuse black body radiation is one third of energy density of radiation.
- (iii) Calculate the black-body temperature of sun from the following data :
Stefan Constant = $1.37 \times 10^{-12} \text{ cal/cm}^2/\text{s}$, solar constant = $2.3 \text{ cal/cm}^2/\text{min}$, radius of the sun = $7 \times 10^{10} \text{ cm}$, distance between the sun and earth = $1.5 \times 10^{11} \text{ m}$

$(2+2)+(1+4)+3=12$

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[Continued]

(3)

(OR)

- (b) (i) State and prove Kirchhoff's law in relation with black-body radiation.
- (ii) What is meant by diffuse radiation?
- (iii) Write the Planck's quantum hypothesis.
- (iv) A black-body of a temperature of 1646 K has wavelength corresponding to the maximum emission λ_m equal to 1.78 micron. Find the temperature of the moon (assumed to be a black-body) if λ_m for the moon is 14 micron.

$(1+4)+2+2+3=12$

3. (a) (i) What is phase space? Show that the volume in phase space corresponding to a discrete quantum state is h^3 .
- (ii) Derive the Maxwell velocity distribution law using MB statistics.
- (iii) A system of distinguishable particles has two non-degenerate single particle energy states O and E. Show that at temperature $T = E/K_B \ln 2$, the probability of a particle occupying the excited state be half that occupying the ground state.

$(2+2)+4+4=12$

[Turn Over]

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(4)
(OR)

- (b) (i) State and prove Sackur-Tetrode equation.
(ii) Show that the partition function for a monoatomic ideal gas is given by

$$Z = \frac{V}{h^3} (2\pi m k_B T)^{\frac{3}{2}}$$

Where symbols have their usual meanings (consider MB statistics).

- (iii) Distinguish between mathematical probability and thermodynamic probability.

- (iv) What are the limitations of MB statistics?
(1+4)+3+2+2=12

4. (a) (i) Name the statistics (BE or FD) obeyed by each of the following particles; neutron, π -meson, photon, neutrino.

- (ii) What do you understand by Bose Einstein condensation? Calculate the critical temperature at which the condensation will start.

- (iii) Write the properties of liquid helium.
2+(2+5)+3=12

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[Continued]

(5)
(OR)

- (b) (i) Derive Planck's law of black-body radiation using Bose-Einstein statistics.

- (ii) Show that maximum entropy of a photon gas is given by

$$S_{\max} = \frac{4V\pi^2 K_B^4 T^3}{45h^3 dc^3}$$

Where symbols have their usual meanings.

- (iii) Discuss the difference between Fermi-Dirac and Bose-Einstein statistics.
5+5+2=12

5. (a) (i) Write the basic-assumptions of FD statistics. Derive the expression for Fermi-Dirac distribution law.

- (ii) Show that for a two-dimensional electron gas, the number of electrons per unit area is given by

$$n = \frac{4\pi K_B T}{h^2} \ln \left(e^{\frac{E_F}{K_B T}} + 1 \right)$$

(2+5)+5=12

[Turn Over]

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(6)
(OR)

(b) (i) Write down the distribution law obeyed by electron gas and apply the same to derive Richardson-Dushman equation.

(ii) Show that if f is the FD distribution function, $-\frac{\partial f}{\partial E}$ is a maximum at Fermi level. Also show that $-\frac{\partial f}{\partial E}$ is symmetric about the Fermi level. $(1+5)+(3+3)=12$

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